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Series Title **AGRICULTURAL MEMORANDUM NO. 1104**

Title **Slope and aspect influence on temperatures - an observational study.**

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Abstract

Between April and September 1988 an observational study was conducted to assess the effects of slope and aspect upon soil and air temperatures. Results confirmed the generally agreed ideas that soil temperatures were higher on the south facing slope. However air temperatures were less affected by slope and at times were lower on the south facing slope compared with the north facing slope and a flat site. Exposure is considered as the main cause of these variations in air temperatures.

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INTRODUCTION

The variation of temperatures at or near to the ground due to the slope and aspect of the land has been discussed in a qualitative manner by many writers, see selected extracts at annex A. The day to day variations may not always be in the same direction but when summed over a period of weeks or months in the form of accumulated temperatures there is likely to be a general increase over a flat surface due to south facing slopes and a decrease due to north facing slopes. These differences have been confirmed by quantitative data and limited theoretical explanation (Lee 1984) for temperatures recorded at or just below the ground level but when related to air temperatures recorded at 1.2 m above the ground, the current literature usually has a vague statement that the effects noticed near the surface are likely to be repeated in the air with a slight reduction in magnitude; a subjective rather than scientific statement.

With the modification of accumulated temperatures (air and soil) being important for a variety of agrometeorological purposes, it was decided to run a pilot study to measure the effects of slope and aspect over a six month period.

THE SITE

The data monitoring was carried out at Talgarth Hill approximately 2 km ENE of the Trawsgoed (Aberystwyth) ADAS Office at about 265 m above sea level. Temperatures were recorded at 3 positions on the hill top (see figure 1). The flat site was on a level area just west of the summit. The south facing 18° slope was exposed to all directions between NE and WNW through S. The north facing 18° slope was less exposed with a large coniferous forest to the NW across a steep valley. Thermistor probes were exposed at 1.2 m in Skye radiation shields and at 10 cm below a bare soil patch (a shallow mineral soil over shale, Powys series). Temperatures were recorded every 30 minutes using Squirrel Data Loggers and there is a Synoptic Automatic Weather Station (SAWS) at 62 m above sea level, between the ADAS Office and the hill top. Midday wind directions from the SAWS have been summarised in Table 2 with the two rows at the bottom indicating whether the slopes are windward or leeward. No attempt has been made to adapt the SAWS wind directions for the different topographic influences between the valley position and the hill top position; the number of calm conditions is likely to be less on the hill top. For the majority of the 6 months south was a windward slope (see Table 4).

THE RESULTS

The monthly temperatures are summarised in Table 1; T_X = maximum, T_N = minimum, T_M = mean.

10 cm Soil Temperatures

Over the six month period, the mean 10 cm soil maximum daytime temperature on the south facing slope was 1.6°C warmer than the flat site, and on the north slope it was 1.5°C colder than the flat site. Within this almost equal and opposite situation there were systematic differences month by month. Table 1 lists the monthly mean soil temperatures for all exposures, also illustrated in figure 2, for where it can be seen that:

a. On the south slope, the difference in maximum temperatures from the flat site declined gradually from 1.7°C (April) to 1.1°C (July) before rising sharply to 2.3°C (September) - figure 2a.

b. On the north slope, the difference in maximum temperatures from the flat site fluctuated between -2.2°C and -2.7°C during the first half of the period before climbing steadily to -0.1°C by September - figure 2a.

c. Between April and June, the loss of heat by day on the north slope exceeded the gain of heat on the south slope - figure 2a.

d. On the south slope, the difference in minimum temperatures from the flat slope remained around 1.2°C (April to June) before declining gradually to -0.2°c by September - figure 2b.

e. On the north slope, the difference in minimum temperatures was small until June before rising briefly to 0.6°C then declining to -0.6°C (September) - figure 2b.

f. The net effect on the mean monthly soil temperatures was for the southerly slope to be consistently just over 1°C warmer than the flat, and the northerly slope to be 1.2 $\pm$ 0.2°C colder than the flat (April to September) and 0.3 $\pm$ 0.1°C colder (July to September) - figure 2c.

Air Temperatures

The 'profit and loss' balance observed in the soil was not so marked in the air with several days when the air temperature on the south facing slope was colder than the north slope. The overall effect for the six month period was for the south facing slope to be only 9 day degrees warmer than the flat position and the north facing slope to be similarly colder than the flat position.

Table 3 summarises the wind direction on the occasions when the south slope was colder than the north slope at 1.2 m in the air. There is a bias towards the days when the south slope was exposed and the north slope sheltered. Table 5 is a similar summary for days when south slope was colder than the flat position.

The exposure to the wind of the slopes is summarised in Table 4. On only 8% of the time was the north slope exposed and the south slope sheltered, with 92% of the time the south slope being exposed to the wind.

General

Increased solar radiation being received by the south facing slope manifested in the soil temperatures was not evident in the air on such an exposed site. The grass growth in the vicinity of the south slope was however more vigorous with the staff visiting the hill needing to cut it more often than the north slope to maintain the required level for consistent observations.

DISCUSSION

10 cm Soil Temperature

The relative differences between daytime soil temperatures on flat and sloping surfaces are primarily due to the gain or loss of direct solar radiation. This gain or loss can be calculated for any given slope and aspect (Thompson and Barrie, 1978). Factors for Talgarth Hill are given in table 6.

Table 6 Fractional differences in direct solar radiation on 18^{o} slope at Talgarth Hill

	South facing	North facing
April	1.176	0.726
May	1.035	0.868
June	0.975	0.927
July	1.000	0.903
August	1.108	0.794
September	1.306	0.596

On average long term statistics for the nearby Aberporth (April-September) show that the direct solar beam accounts for 46% of the incident radiation, the diffuse component making-up 54% (Met. Office, 1980).

Using estimates of total solar radiation derived from sunshine hours observed at Trawscoed (Cowley, 1978) together with the above data an estimate of the radiative input on sloping surfaces can be constructed, see table 7.

Table 7. Solar Radiation Input Trawsgoed 1988 (MJ/m^2/day)

	GLOBAL	DIRECT BEAM			GLOBAL		RATIO TO FLAT	
	FLAT	FLAT	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH
	RG	RD	RDS	RDN	RGS	RGN	RGS/RG	RGN/RG
April	14.2	6.5	7.7	4.7	15.4	12.4	1.08	0.87
May	18.0	8.3	8.6	7.2	18.3	16.9	1.02	0.94
June	18.9	8.7	8.5	8.1	18.7	18.3	0.99	0.97
July	14.3	6.6	6.6	5.9	14.3	13.6	1.00	0.95
August	13.7	6.3	7.0	5.0	14.4	12.4	1.05	0.91
September	10.3	4.7	6.2	2.8	11.8	8.4	1.15	0.81

Note:- RGS = RDS + (RG - RD)
RGN = RDN + (RG - RD)

An examination of the ratio RGS/RG and RGN/RG show that throughout the period the loss to the north slope exceeds the gains by the south slope. This difference is reflected in soil temperatures as shown in figure 2a for the period April to June. The relative radiation receipts in August and September do not however reflect the observations that the north site soil temperatures deviate less from the flat site than do south site temperatures, see figure 2a.

The trend in RGS/RG over the months is reflected in the trend of south slope maximum over flat (figure 2a) in that it declines gradually from April to June before rising to a peak in September as lower solar elevations produce the highest relative enhancements.

However the trend in maximum soil temperature on the north slope compared with flat (figure 2a) is at variance with the RGN/RG ratio. On the north slope the daytime temperatures on the north slope gradually drew closer to the flat site but according to the solar radiation calculations, the relative differences should be increasing. No explanation can be offered for this phenomenon.

On a daily basis the receipt of solar radiation correlates well with the enhanced daytime warming on the south slope, see figure 3 (April) and figure 4 (August). The relationship alters with changing solar elevations so that with a 'low' elevation in April and September the enhancement is effective from daily radiation totals of 650 WH/m^2 upwards, while with 'higher' elevations (supra-optimum) in July and August there is no enhancement below around 1700 WH/m^2.

Air Temperatures

Chizhevskaya (1960) reported that during observation studies in Leningrad, a southerly wind speed of more than 2/3 $m.s.^{-1}$ resulted in a higher air temperature on the north facing slope than on the south facing slope and the reverse effect with a northerly wind blowing. With west and east winds blowing the differences in air temperature on the slope were insignificant. This effect is also evident from these data collected from Talgarth Hill. Table 3 shows that with the wind between 105° and 225°, when the south slope was exposed and the north slope sheltered, over 73% of the days had a higher maximum temperature on the north facing slope. From Table 5, the wind direction 135° to 285° had on average 56% of the days with a higher maximum at the flat site than on the south slope, and again the explanation is largely due to the more exposed south slope site.

SUMMARY

The effects of slope and aspect as recorded at 10 cm below the ground were in line with the results from other workers. The significant reduction of these effects at 1.2 m above the ground was further reduced at such an exposed hill-top site.

CONCLUSIONS

a. The influence of a favourable aspect upon mean air temperature and hence accumulated temperature may be removed by exposure.

b. Crop growth is related to soil temperatures and at Talgarth Hill the higher soil temperatures on the south facing slope were highly correlated with the grass growth during the six month period. Air temperatures would not have indicated this increased growth potential.

c. Further on-site monitoring is recommended including site(s) in valleys with varying slopes.

ACKNOWLEDGEMENTS

Regular visits to the site were made by Dr J Starr and Mr J Tamlyn (ADAS Agromet, Trawsgoed).

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References

Chizhevskaya, M. P. (1960). The radiation and thermal climate of variously aligned slopes under the hill relief conditions of the Leningrad region. Leningrad, Glow. Geol. Obs., T. Vyp. 91, 1960, pp 71-84.

Cowley, I. P. (1978). The distribution over Great Britain of global solar irradiation on a horizontal surface. Meteorological Magazine 107, 357-378.

Lee, M. J. (1984). The effect of aspect upon the temperature of the ground and associated changes in accumulated temperature - Agricultural Memorandum No. 1023 (unpublished).

Met. Office (1980). Solar radiation data for the United Kingdom 1951-75. Met. O. 912. Meteorological Office, Bracknell.

Thompson, N., Barrie, I. A. (1978). Viticulture: the effects of surface slope on direct radiation - Agricultural Memorandum No. 833 (unpublished).

Annex A to Agricultural
Memorandum No. 1104

REFERENCES TO ALTITUDE, SLOPE AND ASPECT EFFECT ON SOIL AND AIR TEMPERATURES

BAKER, C R B - Accumulated temperatures in some pest habitats in 1976-78. Agricultural Meteorology 23 (1981) 245-253

"It is a common observation that snow and frost linger on the north-facing sides of miniature topographical features such as bank and furrows. The data presented here indicates how such small-scale variations in temperature may contribute to the variation in the phenology of animals and plants within a small area .... ".

"Day-degrees are usually accumulated from the screen maximum and minimum temperature observations available from agroclimatological stations in Britain. The differences between the day-degree accumulations in the screen and those in other habitats are evident from the tables. The accumulation from the north slope of the mound were the most similar to those from the screen".

BOYER, D G, FELDHAKE, C M - An optographic analysis of terrain effects on the thermal climate of a steep pasture. Appalachian Soil and Water Conservation Research Laboratory, Beckley, West Virginia (full reference not available).

" ... differences in air temperatures in a steep pasture area were related to slope position as a result of topographic shading, local air circulation and differences in wind velocities."

" ... there is only a small relationship between mean air temperature differences and slope aspect ... however the relationships are strong between mean soil temperature differences ... ".

EXTRACTED FROM DIAGRAM IN PAPER:

Mean* temperature differences	S	SW	W	NW	N	mirror image the same
AIR 25 CM	+0.8	+0.4	+0.1	+0.2	-0.4	
SOIL	+1.9	+1.2	+0.4	-0.2	-1.0	

* Differences between individual site value and the mean temperature for 32 sites.

" ... special differences in air temperature were mainly a result of local air circulated and differences in wind velocities".

" ... slope aspect relationships are strongest at the beginning and end of the growing season".

CARR, M V K - The influence of temperature or the development and yield of maize in Britain. Proceedings of the Association of Applied Biologists. Ann. App. Bio., 1977, 87, pp 261-266.

"In 1974 several sites were selected within and between fields to represent 'warm' and 'cool' situations. At each position crop development was monitored and soil (50 mm) and air (1 m) temperatures estimated using the sucrose technique. During the period of establishment from sowing (30 April) to mid-June differences in mean soil temperature of up to 3°C were measured between sites whilst differences in air temperature were less than 1°C. Over the same interval soil and air temperatures at the 'cool site' were similar but at the 'warm site' the soil was appreciably (2.5°C) warmer than the air".

"In Britain temperatures normally rise slowly in the spring and differences in soil temperatures between fields at this time can have large effects extending even to the time of maturity. Of the various factors controlling soil temperatures at this time shelter from wind is one of the most important whilst slope and aspect and the physical properties of the soil surface such as its colour and texture can also play a part ... ".

CHIZHEVSKAYA, M P - The radiation and thermal regime of variously aligned slopes under the hill relief conditions of the Leningrad region. Leningrad, Glow. Geol. Obs., T. Vyp. 91. 1960. pp 71-84.

"When the southerly wind speed is more than 2-3 m/sec, a higher air temperature is observed on the north slope ie on the leeward slope. When the north winds blow (the south slope being to the leeward), higher air temperatures are observed on the south slope. With west and east winds blowing, the differences in air temperature on the slopes are insignificant .... ".

CROWE, P R - Concepts in climatology. Longman 1971

" ... a hillside location may affect local climate indirectly through such factors as soil drainage, exposure to wind and local movements of the air, but its immediate and direct consequence is to change the angle of incidence of the sun's rays upon the surface of the earth."

"It would appear that, particularly in sunny regions, aspect is a decidedly important factor in local climate. In cloudy Britain, bathed in mild air from the western ocean, its effects are often masked by other climatic factors."

GEIGER, R - The Climate near the ground. Harvard University Press 1966

"Slope climate or exposure climate is determined, in the first place, by the different amounts of direct solar radiation and heat received. This difference can have great significance; for example, a surface inclined at 20° facing toward the south, even allowing for the high degree of cloudiness in Germany, receives roughly twice as much radiation in January as a horizontal surface. The amount of radiation it enjoys is equivalent to a substantial displacement toward the equator."

"The early strawberries that are on sale in Tokyo two months in advance of the main crop are grown on the steep terraces of Shizuoka."

"The radiation received by the slope, however important it may be, is only one of a number of factors in the heat balance and then only during the daytime."

"The question must be raised whether it might not be possible for a special type of climate to develop near the ground on mountain slopes, and whether its temperature contrasts might not be eliminated by the orographic winds generated, particularly when the slopes are steep."

"The highest temperatures near the ground, therefore, are not found at the steep slope but at the bottom of the valley and on the flat mountain plateau, which is protected from the wind by a growth of shrubs."

"The climate of slopes facing in different directions is affected to a large extent by moisture conditions as well as radiation and wind."

" ... the radiative heat received in the forenoon is mainly used to dry the surfaces on which it fails, while in the afternoon most of it is used for heating the soil."

" ... (in the Northern Hemisphere) the warmest slopes are not those facing south but southwest, as a rule."

"The south-western position which we expected to be warmest from the previous discussion, occupies this position only from autumn to spring. The warmest area moves around to the southeast in summer. This is caused by the diurnal variation in cloudiness since, in the Alps, strongly developed cumulus build up by early afternoon, and occasionally produce thunderstorms. More radiation is therefore received by the ground in the forenoon when the cloud cover is less, showing once more how many factors are involved in the determination of slope climate."

GREEN, F H W, HARDING R J - The effects of altitude on soil temperature.
Met. Mag. Vol 108, 1979, pp 81-91

"There is considerable evidence to suggest that many plant physiological processes are more dependent on the temperature of the soil than on that of the air ... and further, that temperature, along with wind speed, is the major constraint on ecological productivity in upland regions ... ".

HARDING, R J - Altitudinal gradients of temperature in the Northern Pennines.
Weather, 34, 1979, pp 190-202

"It can be concluded that for long-term means the maximum temperature is reasonably constant over an upland area, once the mean elevation component has been removed; and the altitudinal gradient is well defined, whereas the minimum temperature is much more site-dependent and only in some comparatively simple cases is the gradient well defined".

" ... the almost linear relationship between the spatial differences of sunshine amounts and those of maximum temperature suggests that it may be possible to calculate the effect of the aspect of a site on the mean maximum temperature."

JONES, R J A, TINSLEY, J, COURT, M N - Mesoclimatic studies in the Upper Don Basin, Aberdeenshire. Met. Mag. 1287. October 1979.

" ... the effect of aspect is confined to April, May and June".

" ... July, August and September the effect was not significant, presumably because most of the sites were on gentle or moderate slopes (3-7 degrees) which reduced the advantage of southern aspects".

" ... in high latitudes, south facing slopes are not always the most favoured in every respect".

SMITH, K - Principles of applied climatology. McGaw Hill, 1975

"Valley climates owe their distinctiveness primarily to two separate but often related factors. These are, first, the degree of slope together with the aspect of the valley sides and, second, the differences in relative relief which inevitably arise in such areas ... but it should also be noted that the climatic characteristics of a particular valley will also depend on the orientation to the prevailing wind and the specific geometry of the relief features involved."

"Data for Arosa at 1890 m above sea level in the Swiss Alps quoted by Kendrew (1938) show that in mid-winter a steep south-facing slope may receive 238 times as much energy as a comparably inclined slope to the north.

	5° S slope	10° N slope
Altitude	375 m	418 m
Whole-spectrum radiation surplus	+77	+49
Evapotranspiration	-5	-5
Sensible-heat flux	-47	-27
Heat flow into ground	-25	-16

Table 2.3 Heat fluxes (langleys/h) on south- and north-facing slopes average over 1100-1400 h on a clear day in August. (After Lowry, 1959).

it can be seen that around midday on a summer day the south-facing slope receives about 50 per cent more radiation than the north-facing hillside and that the heat taken up by the air and soil is increased."

"Although a good deal is now known about the radiation climatology of different slopes experimental observations to determine resultant contrasts in ground and air temperatures have been less successful. This is partly due to the elimination of small thermal differences by wind turbulence on exposed hillslopes but may also be attributed to the complicating effects of other factors. For example, although the total amount of daily solar radiation is received equally around true noon. The temperature does not follow the same symmetrical regime because of the thermal inertia of the earth-air system and the changes in the utilization of energy which take place during the day. In

temperature latitudes, incoming radiation in the morning may be largely used in evaporation and drying the soil compared with the larger proportion available in the afternoon for heating the soil and the air. Because of this, the warmest slopes in the northern hemisphere are often those orientated towards south-west rather than due south. On the other hand, the recurrent development of convective cloud during the afternoon, as reported for the Innsbruck area by Geiger (1969) may lead to the shielding of SW slopes from direct radiation thus producing higher values to the SE orientations.

Soil temperature differences between sunny and shady sites can be quite marked, especially during spells of settled weather. Work by Soons and Rainer (1968) in New Zealand showed that in early September the temperature at 4mm depth on a slope facing NE reached a maximum of only about 13°C around true noon compared with 18°C attained on the slope inclined to the NW some 2½ h after the peak of incoming radiation. Observations by Howe (1955) on a south-facing coastal slope in Wales throughout a fine week in April indicated considerable contracts in the thermal range of the soil between sunny and shaded sites at the 50 mm depth, and on two consecutive June days the exposed site experienced maxima 9.1 and 10.0 degC respectively higher than the shaded position.

Mean daily temperature range (°C) during an April week in 1954 at Aberystwyth

Soil (sunny)	Soil (shady)	Air
6.7 - 17.8	4.4 - 7.8	5.8 - 12.8

As might be anticipated, air temperature contrasts due to aspect are much smaller than observed earth temperature, but measurements at 1.5 m in the Italian Appennines reported by Smith (1967a) for an April day were about 3.3 degC higher on the south-facing slope than at equivalent altitudes orientated towards the north."

THOMPSON, N, BARRIE, I A - Viticulture: the effects of surface slope on direct radiation. Ag Mem 833. Met Office Library, Bracknell

"The success of viticulture in the region of Germany is the result therefore of high temperatures during the growing season caused by the continental summer climate, rather than high solar radiation on the vineyards".

"Increasing vineyard acreage in England ... selection of a site with slope and orientation which maximise the incident radiation may become increasingly important in assuring a successful enterprise".

TABLE 1

			TEMPERATURE RECORDED AT TALGARTH HILL													
			APRIL		MAY		JUNE		JULY		AUG		SEPT			
			MEAN	MEAN - MEAN FLAT											APR-SEPT MEAN DIFFERENCE FROM FLAT	CHANGE TO 6 MONTHS ACCUMULATI TEMPERATUI
AIR TEMPERATURES 10 CM SOIL TEMPERATURES	FLAT	T_X	11.5	-	15.2	-	19.2	-	16.2	-	15.9	-	12.7	-	-	-
		T_N	6.0	-	9.1	-	12.2	-	12.1	-	12.5	-	11.4	-	-	-
		T_M	8.8	-	12.1	-	15.7	-	14.1	-	14.2	-	12.1	-	-	-
	NORTH	T_X	9.2	-2.3	13.0	-2.2	16.5	-2.7	15.1	-1.1	15.3	-0.6	12.6	-0.1	-1.5	-
		T_N	5.9	-0.1	9.1	0.0	12.2	0.0	12.7	+0.6	12.4	-0.1	10.8	-0.6	-0.0	-
		T_M	7.5	-1.3	11.1	-1.0	14.3	-1.4	13.9	-0.2	13.9	-0.3	11.7	-0.4	-0.8	-141
	SOUTH	T_X	13.2	+1.7	16.6	+1.4	20.6	+1.4	17.3	+1.1	17.9	+2.0	15.0	+2.3	+1.6	-
		T_N	7.2	+1.2	10.3	+1.2	13.6	+1.4	13.0	+0.9	12.9	+0.4	11.5	-0.2	+0.9	-
		T_M	10.2	+1.4	13.4	+1.3	17.1	+1.4	15.2	+1.1	15.4	+1.2	13.1	+1.1	+1.2	+220
	FLAT	T_X	11.0	-	14.3	-	16.6	-	14.9	-	16.2	-	14.3	-	-	-
		T_N	4.6	-	7.4	-	10.2	-	10.4	-	10.9	-	9.8	-	-	-
		T_M	7.8	-	10.8	-	13.4	-	12.7	-	13.5	-	12.1	-	-	-
	NORTH	T_X	11.0	0.0	14.2	-0.1	16.6	0.0	14.9	0.0	15.8	-0.4	14.1	-0.2	-0.1	-
		T_N	4.5	-0.1	7.5	+0.1	10.3	+0.1	10.5	+0.1	10.9	0.0	9.7	-0.1	+0.0	-
		T_M	7.7	-0.1	10.9	+0.1	13.5	+0.1	12.7	+0.0	13.3	-0.2	11.9	-0.2	-0.0	-9
	SOUTH	T_X	11.1	+0.1	14.1	-0.2	16.9	+0.3	14.8	-0.1	16.1	-0.1	14.5	+0.2	0.0	-
		T_N	4.7	+0.1	7.5	+0.1	10.2	+0.0	10.4	+0.0	11.1	+0.2	9.5	-0.3	0.0	-
		T_M	7.9	+0.1	10.8	0.0	13.6	+0.2	12.6	-0.1	13.6	+0.1	12.0	0.0	0.0	+9

TABLE 2

	MIDDAY WIND DIRECTION AT TRAWSCOED SAWS												
	345 015	015 045	045 075	075 105	105 135	135 165	165 195	195 225	225 255	255 285	285 315	315 345	CALM
APR	1	0	2	7	4	4	3	2	1	2	2	0	2
MAY	0	1	2	1	4	3	4	1	0	5	6	1	3
JUN	0	0	3	6	1	2	0	1	2	2	9	2	2
JUL	0	0	1	0	0	2	4	2	6	8	5	2	1
AUG	1	0	0	0	0	1	6	3	3	7	8	2	0
SEP	1	1	0	0	0	2	3	2	2	8	6	1	4
TOTAL	3	2	8	14	9	14	20	11	14	32	36	8	12
NORTH SLOPE	W	W	L	L	L	L	L	L	L	W	W	W	-
SOUTH SLOPE	L	L	W	W	W	W	W	W	W	W	W	L	-

L: leeward slope for given range of wind directions
W: Windward slope for given range of wind directions

TABLE 3

	MIDDAY WIND DIRECTION AT TRAWSCOED SAWS (Days when South slope colder than north slope)												
	345 015	015 045	045 075	075 105	105 135	135 165	165 195	195 225	225 255	255 285	285 315	315 345	CALM
APR	1	0	0	1	3	3	1	2	0	0	1	0	0
MAY	0	1	0	0	3	3	4	1	0	3	1	0	2
JUN	0	0	2	3	1	2	0	1	0	1	2	0	2
JUL	0	0	1	0	0	2	4	2	3	5	1	0	0
AUG	0	0	0	0	0	1	2	0	0	2	0	0	0
SEP	0	0	0	0	0	0	2	2	0	1	1	1	2
TOTAL	1	1	3	4	7	11	13	8	3	12	6	1	6
NORTH SLOPE	W	W	L	L	L	L	L	L	L	W	W	W	-
SOUTH SLOPE	L	L	W	W	W	W	W	W	W	W	W	L	-
% OF ALL WINDS	33	50	37	28	78	78	65	73	21	37	17	12	50

% is derived from ratio of 'Total' for given range of wind directions in this table 3 (when S slope is colder than N) to the corresponding 'Total' in Table 2 ie Direction 165°-195°: 13/20 (65%)

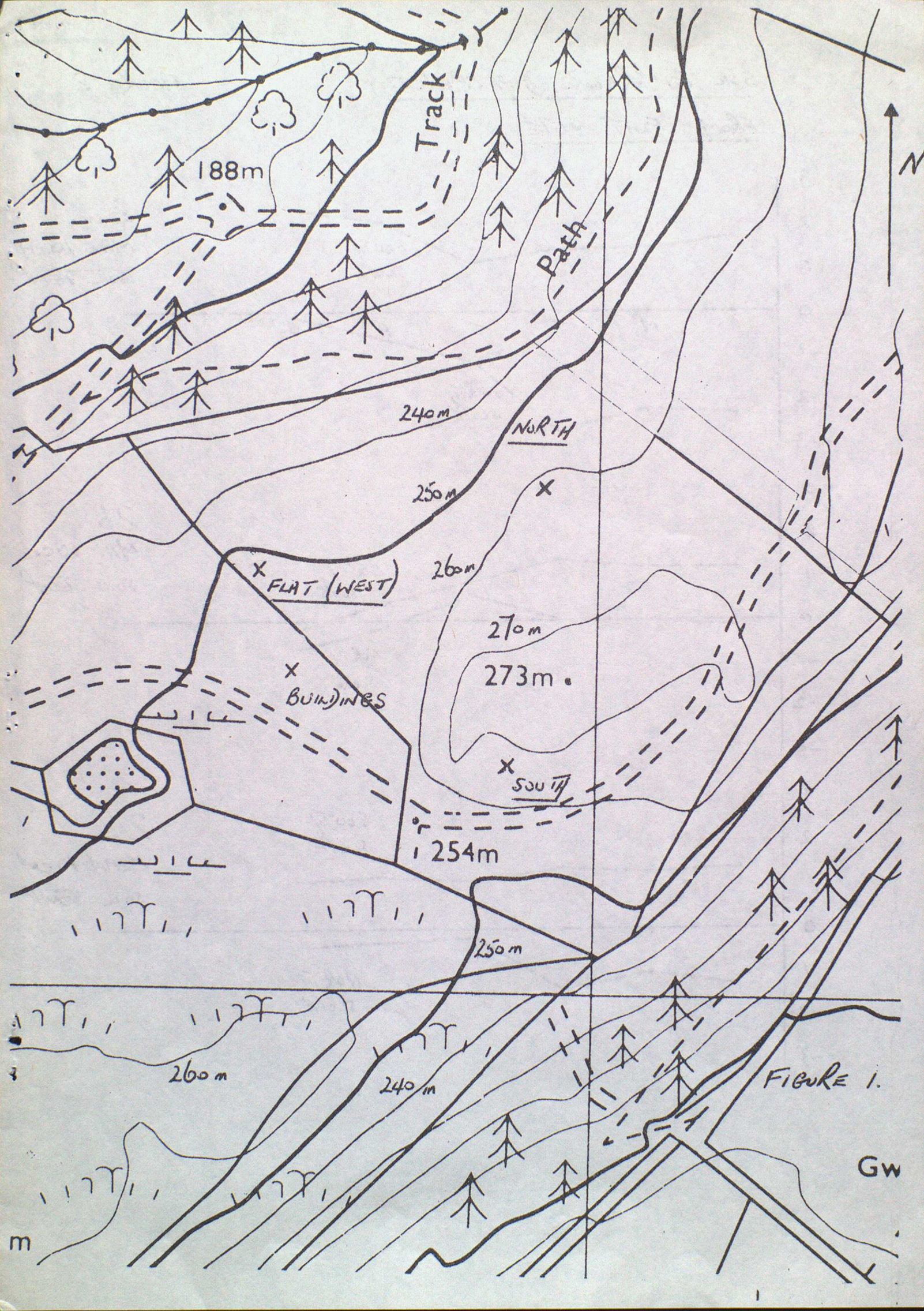
TABLE 4

	DAYS EXPOSED TO WIND	DAYS EXPOSED TO WIND AND OTHER SLOPE SHELTERED
SOUTH FACING SLOPE	158 (92%)	90 (53%)
NORTH FACING SLOPE	81 (47%)	13 (8%)

EXCLUDING CALM

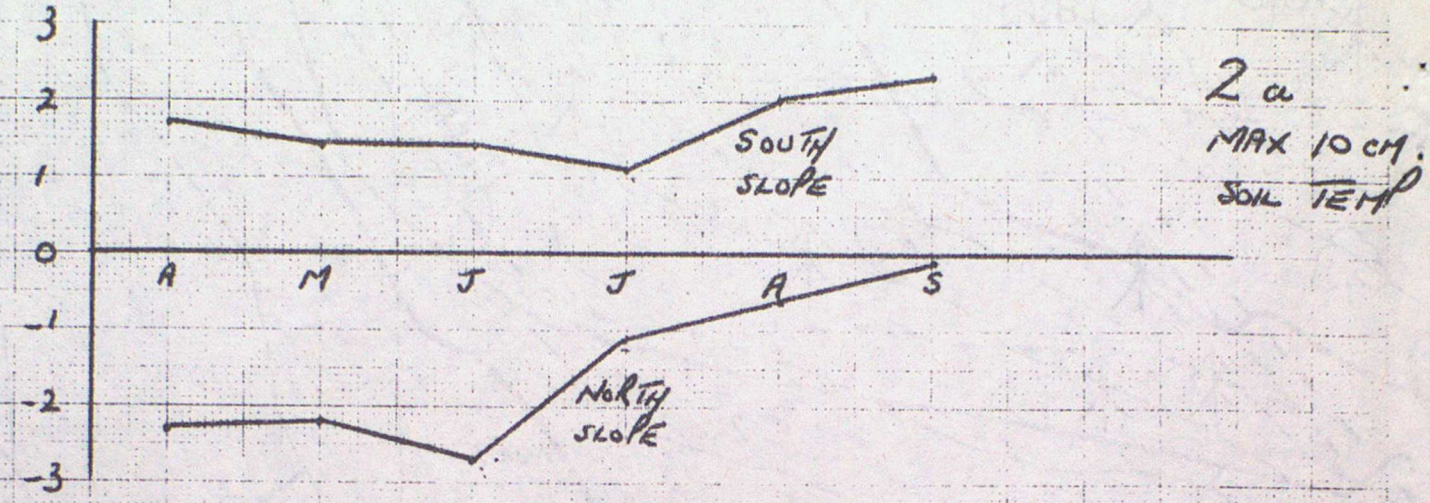
TABLE 5

	MIDDAY WIND DIRECTION AT TRAWSCOED SAWS (Days when South slope colder than flat site)												
	345 015	015 045	045 075	075 105	105 135	135 165	165 195	195 225	225 255	255 285	285 315	315 345	CALM
APR	0	0	1	1	2	2	2	0	0	1	1	0	0
MAY	0	0	0	0	2	2	2	1	0	5	3	0	2
JUN	0	0	1	4	0	2	0	0	0	0	1	1	1
JUL	0	0	0	0	0	2	2	1	3	8	2	1	0
AUG	0	0	0	0	0	0	4	2	2	3	6	1	0
SEP	0	0	0	0	0	1	1	2	1	4	2	0	0
TOTAL	0	0	2	5	4	9	11	6	6	21	15	3	3
NORTH SLOPE	W	W	L	L	L	L	L	L	L	W	W	W	-
SOUTH SLOPE	L	L	W	W	W	W	W	W	W	W	W	L	-
% OF ALL WINDS	0	0	25	36	44	64	55	54	43	66	42	37	25

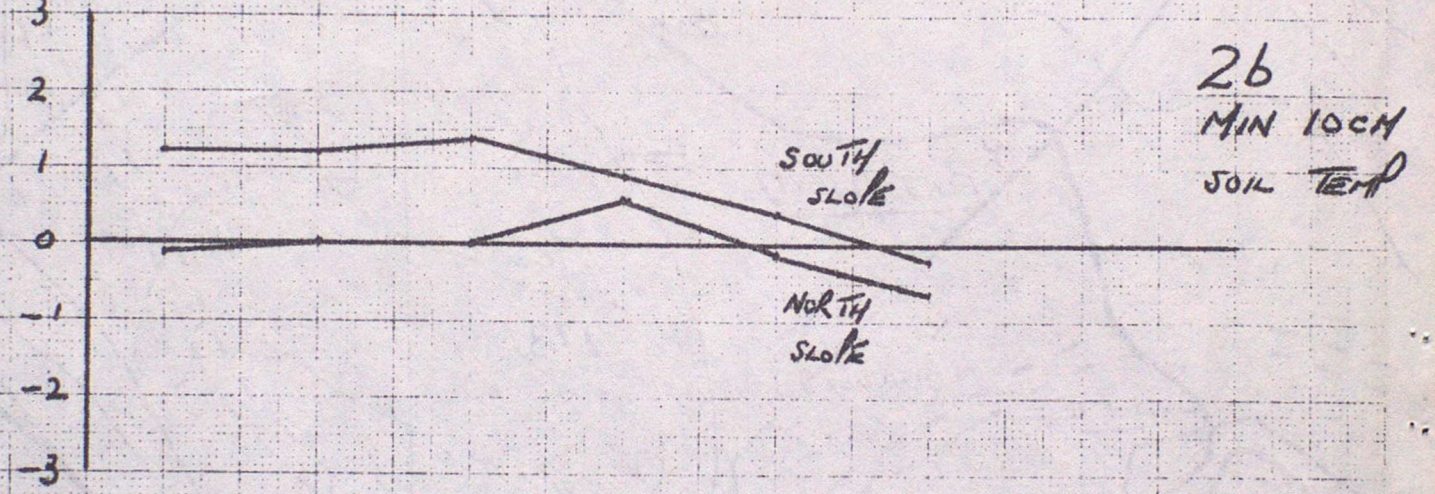

Track
188m
Path
N
240m
NORTH
250m
260m
FLAT (WEST)
270m
273m
BUILDINGS
SOUTH
254m
250m
260m
240m
FIGURE 1.
Gw
m

SOIL TEMPERATURE DIFFERENCES FROM FLAT SITE

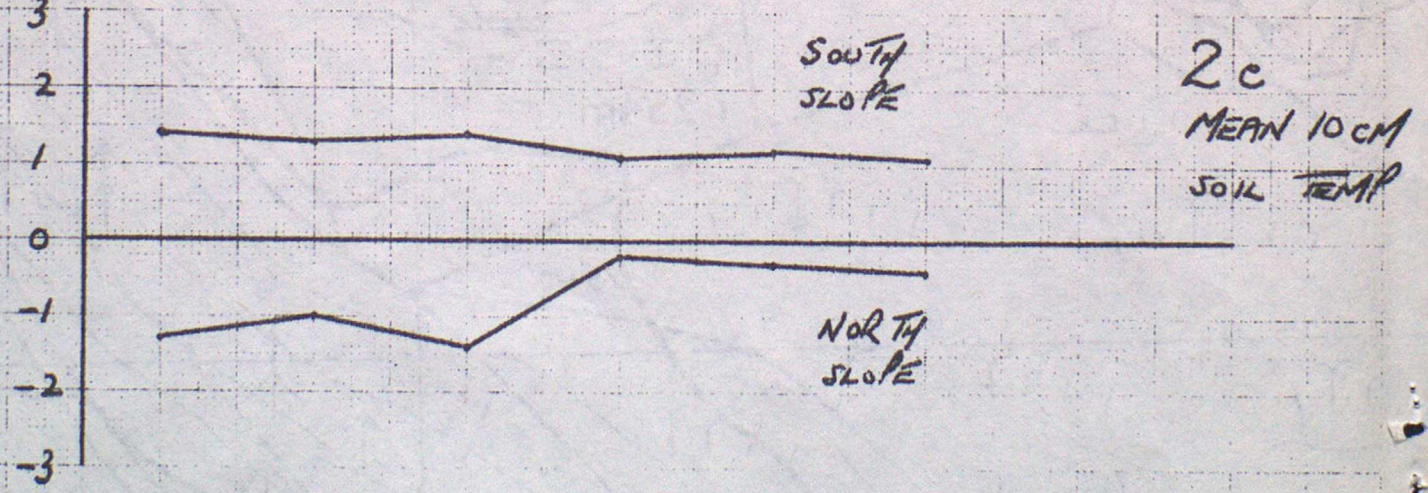
FIGURE 2



2a MAX 10 CM. SOIL TEMP



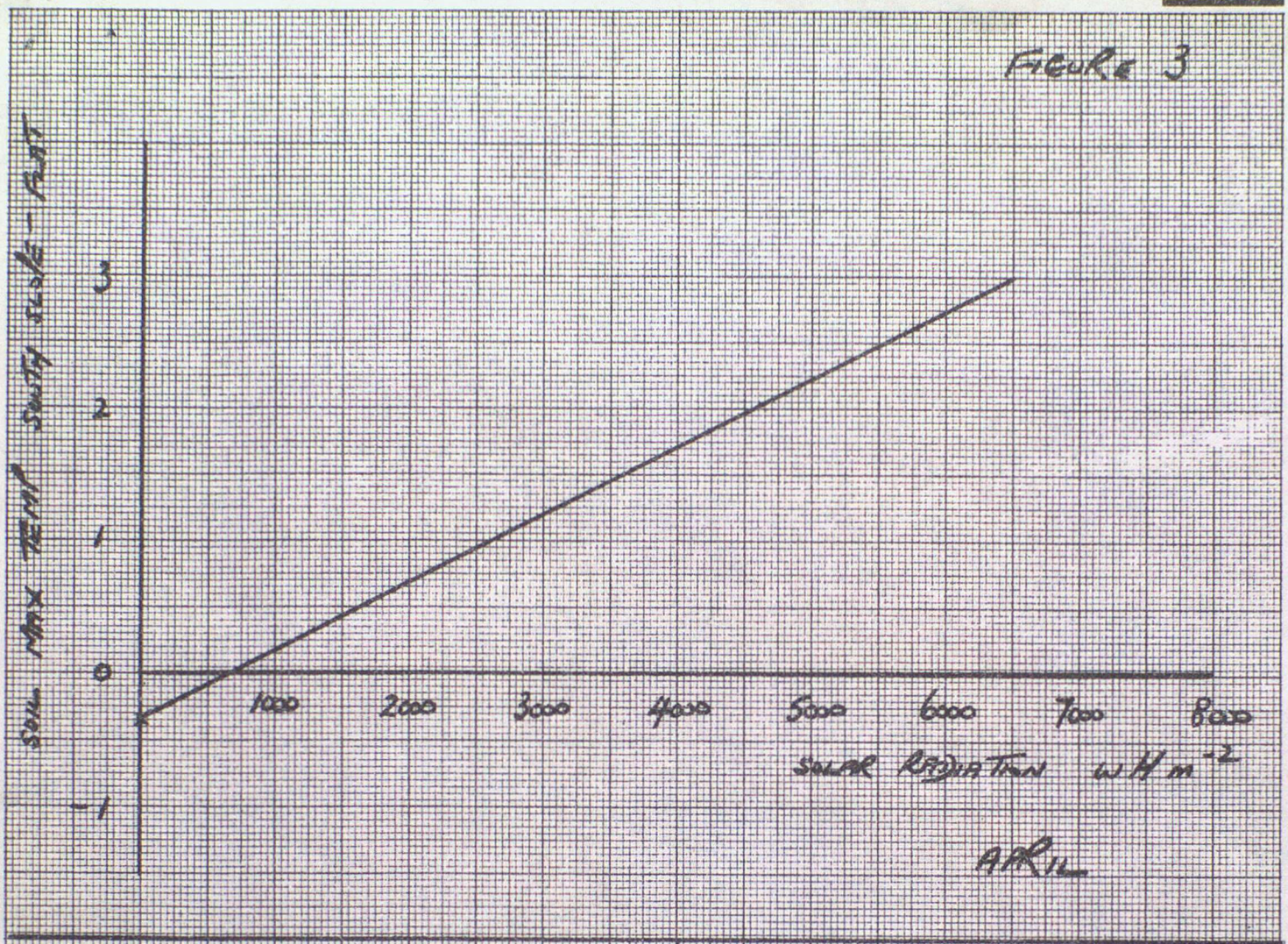
2b MIN 10CM SOIL TEMP



2c MEAN 10 CM SOIL TEMP

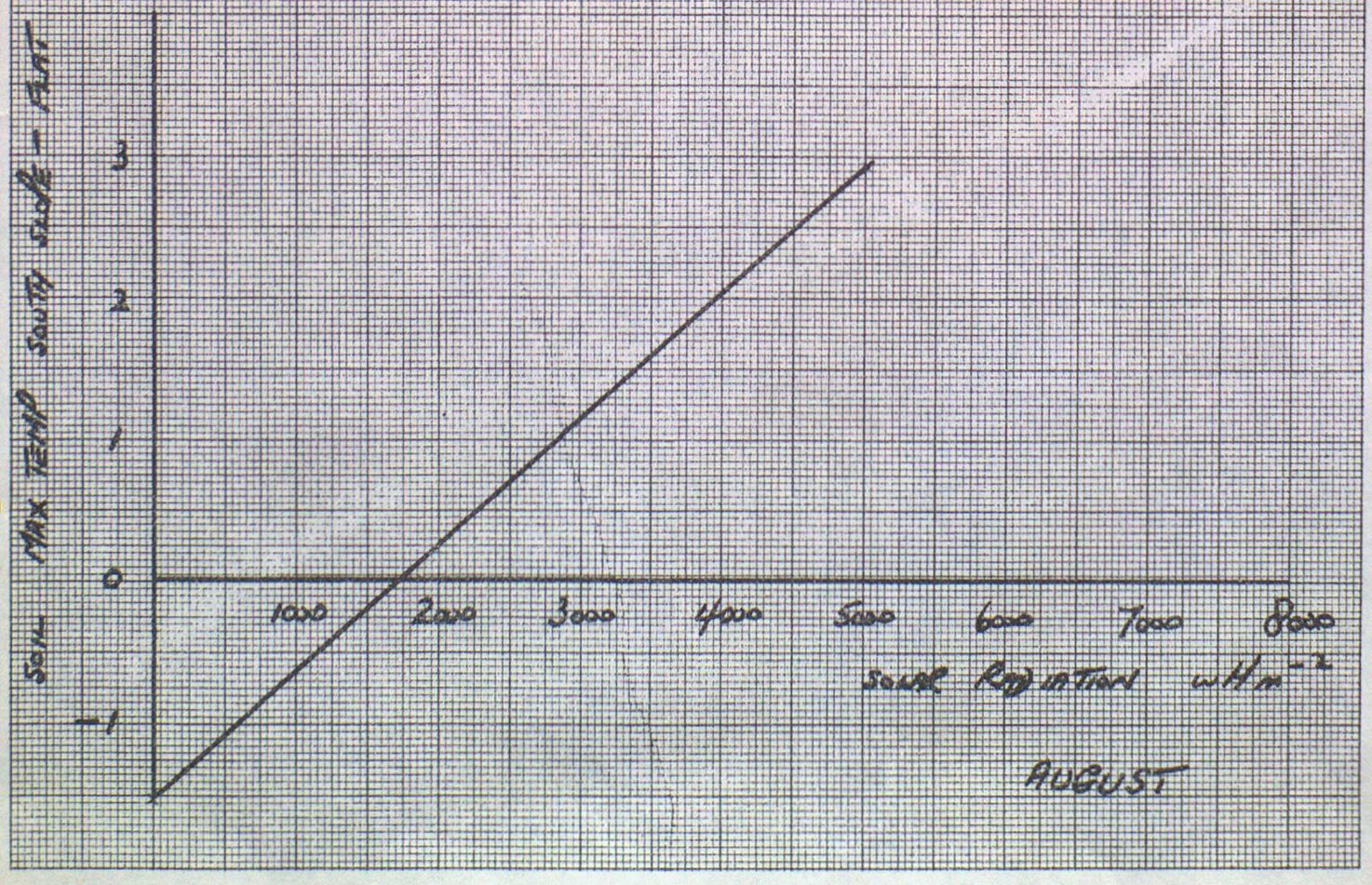
Chartwell

FIGURE 3



APRIL

FIGURE 4



AUGUST